THE PROMISE OF IMMERSIVE LEARNING:

Augmented and Virtual Reality's Potential in Education



ELLYSSE DICK AUGUST 2021

INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION

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KEY TAKEAWAYS

AR/VR solutions can enhance classroom experiences and expand opportunities at all levels of learning. The federal government should support further innovation by investing in research, skill-building, content development, and equitable adoption of immersive technologies.

- AR/VR technologies are a promising addition to the "edtech" space due to their immersive nature, ability to share information in new and engaging ways, and potential to offer virtual experiences that can mitigate barriers from cost or distance.
- Although still in its early stages, there are many promising examples of this technology already in use in K-12, higher education, and teacher training. Applications range from STEM education and technical training to arts and humanities.
- AR/VR can provide K-12 educators with interactive and engaging tools for classroom learning. These include libraries of immersive content, experiences for specific subjects or learning objectives, and tools for students with learning disabilities.
- INTRODUCTION

Digital technologies are continually transforming the field of education. In a 2019 Gallup survey, 65 percent of U.S. public school teachers said they used digital tools every day, while 13 percent used them a few days a week - and 85 percent saw "great value" in using them in the future.1 As momentum for educational technologies continues to grow, educators and institutions are looking for new ways to integrate digital solutions into classroom experiences. Augmented reality and virtual reality (AR/VR) – immersive technologies that enable users to experience digitally rendered content in both physical and virtual spaces - offer notable potential for edtech innovation. These technologies expand the possibilities of learning environments from K-12 classrooms to medical schools by reducing barriers from physical space, enhancing collaboration and hands-on learning, and providing individualized learning approaches that can help students at all levels thrive.

AR/VR as an educational tool is hardly a novel concept. But immersive learning has only recently transitioned from small-scale experimentation to

- In higher education, AR/VR can help learners grasp abstract concepts and gain handson experience in low-risk virtual settings. This can enhance STEM courses, medical simulations, arts and humanities materials, and technical education.
- Congress should direct the Department of Education to invest in programs, resources, and initiatives that will guide the development of AR/VR educational solutions and encourage further innovations in this field.

a multimillion-dollar market with rapidly growing use.² Classrooms across the country use AR/VR for virtual field trips, science experiments, immersive simulations, and more. Many basic experiences are compatible with mobile devices, and advanced headsets simultaneously improve in quality and decrease in cost. The technologies necessary to develop and access immersive content are also becoming easier to use and more affordable.³ This report explores the current state and potential contributions of AR/VR in education and highlights a sampling of the solutions across subjects and learning levels that are building the foundation for the immersive classrooms of the future.

Policymakers can play a valuable role in accelerating adoption and encouraging innovation to realize the full potential of AR/VR technologies in education. Congress should direct the Department of Education to help to bridge existing knowledge and content gaps by:

 investing in research into best practices to mitigate health and safety concerns for young children, and providing guidance on age-appropriate use;

- providing resources and opportunities for educators to develop the skills and knowledge needed to successfully deploy these technologies, and developing resources and guidance to integrate AR/VR technologies into digital literacy initiatives to reduce the "learning curve" for students at all levels;
- accelerating the development of quality, relevant, and age-appropriate immersive educational content by investing in government educational content for AR/VR and expanding AR/VR innovation in colleges and universities; and
- supporting initiatives to expand access to AR/VR devices and applications.

THE VALUE OF AR/VR IN EDUCATION

Researchers have been exploring the potential of immersive technologies as an educational tool since at least the 1990s.⁴ AR/VR technologies are a promising addition to the growing field of education technology because of their immersive experiences, their ability to share information in new and engaging ways, and their potential to offer virtual experiences that expand access to educational opportunities that would otherwise be limited by cost or physical distance. However, AR/ VR devices and applications have only recently become affordable and user-friendly enough for these solutions to actually be implemented in classrooms.

AR/VR technologies offer a wide range of capabilities to present information in more interactive ways than their two-dimensional counterparts. At the highest level, advanced VR systems can fully immerse users in a virtual environment, where they can interact with virtual objects as well as other individuals in real time. This kind of experience lends itself to hands-on learning that either simulates real-world experiences or presents complex information in ways that would not otherwise be possible. For example, students can view microscopic objects in 3D, or stand in the middle of a physics simulation. VR also offers the ability for users to enter pre-recorded 360-degree visual experiences – either still images or video – they can view but not manipulate or interact with. This less-immersive (but often lowercost) approach can be beneficial when the visual

presentation or sense of presence is the most important element of a given experience, such as visiting a historical site.

With AR, or mixed reality (MR), users can interact with virtual objects that appear within their physical surroundings. This is most beneficial for scenarios wherein users need to interact with virtual objects while also maintaining situational awareness of their physical environment. For example, students could follow digital overlays of instructions for complex activities such as learning how to repair a complex machine or conducting a medical procedure. Much like VR, AR also offers less-interactive experiences, allowing users to view static virtual objects or information within physical space. This is most beneficial when the object itself holds the most educational value – such as placing a virtual model of a sculpture or historic artifact in a classroom, or overlaying additional text or images on a historical site.

There is growing enthusiasm among students and educators – as well as parents, administrators, and institutions – around using immersive technologies as educational tools.

- In a 2016 survey of 1,000 U.S. teachers conducted by Samsung Electronics and GfK, 93 percent said their students would be excited to use VR, and 83 percent believed these technologies could help improve learning outcomes.⁵
- In a 2017 joint report from digital and VR content companies and the DigiLitEY academic network, 70 percent of U.S. children ages 8 to 15 and 64 percent of parents expressed interest in VR experiences.⁶
- In a 2018 study from Common Sense Media, 62 percent of parents overall – and 84 percent of parents who had used it themselves – believed VR could provide their children with educational experiences.⁷
- Another 2018 survey finds that just under 50 percent of higher education institutions have either partially or fully engaged in VR deployment.⁸
- In a 2020 survey from Perkins Coie and the XR Association, respondents named education as the second most likely sector to be disrupted by immersive technologies in the near future.⁹

AR/VR-based education tools offer enormous potential to transform the way students of varying ages and disciplines learn. Indeed, although research into the value and efficacy of AR/VR in education is ongoing, several studies indicate that AR/VR tools can enhance learning outcomes in both K-12 and higher education settings.¹⁰ Immersive solutions can present opportunities for educational experiences that would otherwise require significant travel or resources, such as visiting a faraway location or performing experiments in a laboratory. These experiences can also transcend physical space limitations to create educational opportunities that would not otherwise be physically possible, such as visiting another planet or period in history or manipulating enlarged models of microscopic objects. Further, AR/VR experiences can engage students in handson, gamified approaches to learning in a variety of subjects - which have been shown to support cognitive development and increase classroom engagement.¹¹

In addition to offering new types of experiences for all learners, AR/VR tools can improve overall learning outcomes for students.¹² Immersive experiences have been shown to reduce cognitive load and distance, encourage higher engagement, and improve memory recall for complex or abstract topics, such as STEM (science, technology, engineering, and mathematics) subjects that often rely on two-dimensional representations of otherwise intangible concepts.¹³ And individual-level immersive learning allows for more personalized approaches that can accommodate different learning styles, speeds, and abilities.¹⁴ For certain types of learning, they can also provide feedback to students and educators and adjust individual learning objectives to meet students where they are – helping students realize their full potential and leaving fewer of them behind.¹⁵

AR/VR in K-12 Education

Due to the unique capabilities of these technologies, immersive solutions are gaining popularity among K-12 educators and administrators. AR/VR solutions can either enhance, partially replace, or fully substitute for traditional classroom learning. Perhaps the most common use in K-12 settings currently is enhancing classroom experiences. For example, teachers can walk students through immersive virtual field trips or allow students to interact with 3D models using AR. However, schools are also turning to AR/ VR solutions for blended and distance learning. The pivot to online and hybrid learning during the COVID-19 pandemic highlighted the value of teaching tools not being tethered to a physical location.¹⁶

Immersive technologies allow students to passively participate in remote learning experiences and engage with instructors and peers in real time using shared virtual elements.¹⁷ For example, mobile AR allows students to view a painting on their wall or an object in their living room, while AR/VR-based virtual labs would allow them to conduct hands-on experiments regardless of whether they are present in a fully equipped classroom or laboratory. Fully immersive VR experience also have the advantage of reducing distractions during remote learning, thereby encouraging students to be fully present during lessons.

AR/VR technologies also offer promising tools to engage students – both in the classroom and remotely – with autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), dyslexia, or other cognitive or learning disabilities.¹⁸ For example, VR experiences can help treat phobias in young people with ASD.¹⁹ Meanwhile, AR can assist students with learning disabilities by altering or enhancing physical learning tools such as textbooks or flash cards.

AR/VR in Higher Education

AR/VR technologies are equally valuable in more advanced learning environments. College and university educators across disciplines are implementing immersive technologies in their courses.²⁰ In a 2018 survey of higher education institutions from Internet2, over two-thirds of institutions had either partially or fully deployed AR/VR solutions, and one-third were testing them.²¹ Some academic institutions have even introduced dedicated spaces that allow students and faculty to access AR/VR devices and develop their own content. These dedicated labs, as well as hardware students either own or borrow, create new opportunities for students and educators to experiment with immersive learning (see box 1).

AR/VR ACCESS AND CONTENT DEVELOPMENT AT HIGHER EDUCATION INSTITUTIONS

AR/VR labs, lending programs, and similar efforts can accelerate adoption of AR/VR edtech solutions at colleges and universities. These programs often provide students with their first hands-on experience with immersive technologies, and serve as a resource for faculty looking to integrate AR/VR solutions into their lessons. Interest in these offerings is growing: In the same Internet2 survey, although less than one-third of institutions (27 percent) were using AR/VR as part of their production IT environment, about half (53 percent) planned to deploy these technologies within the next three years.²²

The following are three examples of existing programs introducing students and faculty to immersive learning.

The Harvard Innovation Labs AR/VR Studio is open to all full-time, degree-seeking Harvard students.²³ The studio includes a selection of AR/VR devices as well as content production equipment and software, and offers open sessions as well as guided workshops that encourage students to explore the potential of this technology.

Colorado State University launched an Immersive Reality Training Lab in 2019 to accommodate up to 100 students for simultaneous immersive learning experiences.²⁴ Part of the university's Health Education Outreach Center, the lab was designed to enhance biomedical education with immersive simulations – without burdening students or faculty with the necessary equipment costs.

The University of Michigan XR Initiative,

part of the university's Center for Academic Innovation, provides funding and guidance for faculty projects that implement AR/ VR technologies across disciplines.²⁵ The university also has several onsite labs with AR/VR devices and offers an equipment checkout service.²⁶ One well-established use of AR/VR in higher education is immersive simulations. Virtual simulations offer relatively low-cost alternatives to more traditional in-person scenarios while maintaining a level of immersion that makes participants feel like they are "really there."²⁷ This is particularly useful for high-cost or high-risk scenarios, such as in health care education.²⁸ Indeed, the cost of requisite software for a virtual simulation can be as low as one-tenth the cost of physical alternatives in medical education.²⁹ Beyond medical education, virtual simulations can also facilitate soft-skills training, such as negotiation and communication skills.³⁰

Immersive learning can also supplement career and technical education. Much like scenario-based simulations, AR/VR solutions allow individuals to build skills through hands-on experience while also minimizing both the cost and risk associated with field training.³¹ For example, students can practice operating or repairing 3D models of complex machinery to build familiarity and safety awareness before handling the real thing. Immersive tools for technical education can also better prepare students to utilize these and other emerging technologies in their chosen fields.³² This baseline knowledge will be increasingly valuable as industries such as construction and advanced manufacturing continue to adopt AR/VR and other advanced technologies.

Finally, AR/VR solutions can enhance research collaboration as well as hybrid learning models.33 Immersive environments allow students and instructors to interact face to face and in real time, regardless of where they might be physically located. Immersive collaboration could mitigate many of the factors that contribute to "Zoom fatigue" - a growing concern, as long-distance collaboration and communications increasingly rely on videoconferencing - such as cognitive load, restricted mobility, and prolonged eye contact.³⁴ In fully digital environments, all participants can also interact with virtual objects, including complex 3D models that would be costly to reproduce in the real world. MR solutions can also enhance hybrid collaboration and learning models that combine both in-person and virtual interactions; for example, by allowing an instructor to communicate with remote students by video chat while simultaneously conducting an in-person demonstration.

AR/VR for Educators and Administrators

Immersive technologies can enhance not just learning environments but also broader education systems. Just as immersive solutions can improve learning outcomes for students, they can also serve as valuable tools to better equip teachers for success.³⁵ Virtual training allows educators to hone their skills with simulated, virtual students first before doing so in a real-world classroom where their actions could significantly impact students' lives.³⁶ As the technology continues to grow and develop, administrators and officials may also find value in leveraging immersive solutions for collaboration, communication, and community engagement.

Public Resources

The Smithsonian Institution offers a repository of open-access 3D models that allow users to view items from Smithsonian museums' collections in their physical surroundings using AR on a mobile device.³⁷ Unlike print or digital two-dimensional representations, these models give the viewer a sense of scale and allow them to interact with them in three-dimensional space. Educators can use these resources to enhance classroom learning in subjects such as natural and U.S. history. The initial collection comprises 10 items, including full-size skeletons, cultural objects, and statues, all available with any camera-enabled mobile device on the web-based Voyager platform.³⁸

CURRENT APPLICATIONS OF AR/VR TECHNOLOGIES IN EDUCATION

AR/VR technologies offer significant potential to enhance learning at all levels and across disciplines. As immersive technologies evolve, new use cases in educational contexts are continually emerging. This section highlights some of the recent innovations that are building the foundation for the future of immersive educational technologies.

K-12 Education: Enriching Classroom Experiences and Expanding Opportunities

Immersive technologies have the potential to create more engaging, effective, and equitable learning environments for children. Current solutions in this space include libraries of immersive content suitable for educational use, specialized content for targeted subjects and learning levels, and tools developed specifically to support students with learning disabilities.

Immersive Learning Curricula and Resource Collections

Many existing AR/VR products for K-12 learning offer preset curricula and collections of immersive experiences teachers can adapt to specific learning objectives. Existing offerings include publicly available resources from government agencies, education-focused collections from libraries of immersive content, and specialized services from companies focusing specifically on implementing AR/VR in immersive experiences. Figure 1: The Smithsonian Institution's AR tools allow users to view life-size replicas of popular exhibits—such as this mammoth skeleton from the Museum of Natural History—in their own physical surroundings. *Image source: Smithsonian Institution via Instagram.*³⁹



The National Aeronautics and Space Administration (NASA)

also offers publicly available immersive educational resources instructors can integrate into lesson plans or broader learning experiences in museums or planetariums. These immersive experiences can place students in scenarios that would otherwise be impossible – such as experiencing life onboard the International Space Station or exploring another planet.⁴⁰ In 2018, NASA released a VR experience that allows users to view a rocket launch from the launchpad.⁴¹ The agency also offers a collection of web-accessible 360° videos users can view on either a headset, computer, or mobile device.⁴²

Content Collections

The New York Times guide to "VR in the Classroom" includes lesson plans that integrate the publication's collection of 360° videos.⁴³ The guide includes lesson plans for STEM and humanities subjects and stepby-step instructions for teachers who may not have extensive experience integrating immersive content in their classrooms. Although the lesson plans offer a beneficial resource, teachers can also use the 360° videos as standalone tools. The videos can be viewed on a computer or mobile device or using a head-mounted display.

Figure 2: The "NASA SLS Oculus Rift Experience" lets users explore a virtual model of the Space Launch System (SLS) rocket and watch a simulated launch from the launchpad—an experience that would not be possible in the real world. *Image source: National Aeronautics and Space Administration (NASA)*⁴⁴ **The Google Arts and Culture** platform hosts many of the experiences that were previously part of Expeditions, which is an app that allows teachers to build and lead virtual field trips.⁴⁵ The platform contains 360° experiences, including artwork, space exploration, natural history, musical performances, and cultural and historical sites around the world.⁴⁶ Educators can use these experiences to build full virtual excursions or enhance classroom lessons.

Edtech Services

ClassVR is a full-service immersive education platform from edtech provider Avantis.⁴⁷ The service includes both the requisite hardware (plastic VR headsets) and a library of curriculum-aligned immersive educational content, which teachers can control from a centralized management system on a single computer.⁴⁸ Unlike decentralized libraries that do not allow teachers to control the experience once students are in-headset, this system allows teachers to integrate VR into guided lessons.

Kai XR is a subscription-based immersive learning platform that was developed to address opportunity gaps in education – namely access to field trips and other off-site enrichment activities.⁴⁹ The platform offers guided, multilingual virtual field trips to museums, monuments, historical sites, and even outer space.⁵⁰ The company offers affordable headsets, but the platform is also accessible on computers and mobile devices. In addition to field trips, the platform includes tools to teach students how to build their own immersive spaces and virtual experiences.



Figure 3: With basic headsets and a mobile device, educators can integrate immersive content collections such as virtual field trips to otherwise inaccessible locations — into their lesson plans at relatively low cost. Image source. *Image source: iStock.*⁵¹



Subject Specialization

While some K-12-focused products offer a wide selection of content to cover a variety of subjects, others offer experiences for specific subjects or learning objectives.

BioDive by Killer Snails is a web-based VR experience built to teach middle school students about marine biodiversity.⁵² Students explore an underwater ecosystem as marine biologists, and the app prompts them to make observations and develop hypotheses in an online journal. Teachers can view individual student progress and help guide their learning. Students can access both the immersive experience and the online journaling feature on any web-enabled device. **Movers and Shakers** develops AR tools to integrate Black experiences in middle school history curricula.⁵⁴ Most recently, the organization launched Kinfolk, an app that lets students interact with AR models of Black leaders throughout history, such as Frederick Douglass, Harry Belafonte, and Shirley Chisholm.⁵⁵ Users can view each figure's digital "monument" and access related content such as their biography, related historical artifacts, and even playlists.

Special Education

AR/VR's ability to provide individualized learning solutions can benefit all students, including those with cognitive and learning disabilities. In addition, there are immersive programs available specifically for special education, particularly for students with ASD.

Project VOISS (Virtual Reality Opportunities to Implement Social Skills) is a Department of Education-funded program based out of the University of Kansas Center for Research on Learning and Department of Special Education.⁵⁶ The project uses VR experiences to help middle school-aged students with learning disabilities develop and practice social skills. The program provides students and teachers with a low-risk, controlled environment to practice many common scenarios with a headset or web-enabled device.⁵⁷

Floreo offers VR-based lessons in social and life skills for young people with ASD.⁵⁸ Through storybased interactive scenarios, users can practice conversations and social cues in a gamified environment. Educators or other supervisory figures can view progress and guide the experience via an application on a tablet or mobile device. The experiences focus on building social connections, simulating real-life interactions, and practicing emotional-regulation techniques.⁵⁹



Figure 4: BioDive lets students experience a marine expedition from an immersive, first-person view. *Image source: Killer Snails.*⁵³

Figure 5: With immersive simulations such as Floreo, students can practice interactions they might experience in their daily lives, such as conversations with peers, in a controlled, low-risk environment. *Image source: Floreo*.⁶⁰



Higher Education: Making the Theoretical Tangible and Equipping Students for Their Futures

Higher education solutions combine the learning advantages of immersive experiences with AR/VR's capacity to reduce barriers found in physical space. They are often more decentralized than their K-12 counterparts, giving students more opportunities to learn and explore independently with guidance from instructors. STEM and health care education have long stood at the forefront of immersive learning, but colleges and universities in particular are increasingly turning to AR/VR solutions to enhance education in less-obvious fields, including humanities and art, and even professional fields such as law and business.

STEM Education

Immersive experiences can be particularly beneficial in STEM education because they offer hands-on experiences that would be either logistically difficult or physically impossible in the real world. A growing number of STEM faculty and educational technology experts are developing creative ways to teach complex and often abstract concepts using AR/VR tools.

Polar Explorer is a VR teaching tool developed by researchers at Arizona State University, Northern Arizona University, the University of Arizona, and the University of Colorado Boulder to teach undergraduate students about the impacts of climate change on polar environments.⁶¹ The program takes students through interactive virtual field trips to the Arctic – an experience that few would have the financial resources or physical ability to have in real life.

Faculty at **Universidad Católica San Antonio de Murcia** in Spain used a VR environment built in the web-based Mozilla Hubs to develop hands-on lessons about the coronavirus.⁶² Not only could students explore learning tools such as a largerthan-life model of the virus, they could do so in real time alongside their professor and peers in a virtual environment at a time when in-person collaboration was not possible due to COVID-19 safety measures.

At **Purdue University**, astronomy students can explore interactive, 3D models of astronomical objects in a virtual, collaborative environment.⁶³ Students and the professor can access the virtual space from anywhere using a headset or a computer, allowing the instructor to guide students through lessons that would otherwise rely on two-dimensional representations of these distant and complex phenomena.

Figure 6: Students in Professor Danny Milisavljevic's astronomy class investigate 3D models of astronomical objects alongside their peers in a virtual environment. *Image source: Purdue University*.⁶⁴



The Air Force Academy is integrating MR solutions into chemistry lessons through a new platform called HoloChem.⁶⁵ Developed by GIGXR (a company that produces AR, VR, and MR learning systems for STEM and medical education), the platform allows cadets to conduct advanced

chemistry experiments that would be dangerous to execute in real-life labs, particularly by lessexperienced learners.⁶⁶

Medical Training

Medical education requires significant handson, in-person learning to prepare students for everything from interacting with patients to completing complex procedures. Medical and health care educators are increasingly turning to AR/VR solutions to provide low-cost, low-risk, and often more interactive alternatives to traditional approaches in this field.

HoloAnatomy is a medical education program developed at Case Western Reserve University that uses Microsoft HoloLens MR devices to enhance anatomy curricula.⁶⁷ Rather than a traditional cadaver-based approach, HoloAnatomy allows students to interact with 3D anatomical models and receive real-time feedback. The collaborative, MRbased approach also lends itself to remote learning, which proved critical for medical education during the COVID-19 pandemic.⁶

Figure 7: Using HoloAnatomy software and MR headsets, medical and life sciences students can view and manipulate anatomical models in real time. *Image source: Interactive Commons at Case Western Reserve University*.⁶⁹



Oxford Medical Simulation is a VR-based medical simulation platform that allows learners to practice patient care scenarios, from taking a medical history to administering treatment.⁷⁰ After completing a simulation, students receive individualized feedback and can re-enter the scenario multiple times to improve their performance. The software can also be used remotely on a computer if students do not have access to a headset.

Imperial College of London's School of Medicine

launched a remote clinical teaching program using the Microsoft HoloLens to improve remote and distance learning during the COVID-19 pandemic in 2020.⁷¹ As a substitute for the hands-on clinical experience necessary for medical education, clinicians wear HoloLens devices that record a live feed of their patient interactions during their rounds. Not only can students observe these interactions in real time but they can also interact with the clinician to ask questions just as they would when observing rounds in person. Virtual access also means an experience that would normally accommodate a handful of students is now much more widely accessible.⁷²

Arts, Humanities, and Other Disciplines

AR/VR tools in higher education extend beyond hard sciences to enhance learning across disciplines. Increasingly, faculty and researchers across subject areas are taking advantage of the immersive, engaging, and information-rich experiences these technologies offer.

A visiting professor at **Hamilton College** offered a course in 2018 titled "Dream a Little Dream: Virtual Realities and Literature," which encouraged students to engage with literary texts by creating their own literature-inspired VR environments.⁷³ Students were able to develop important skills in the humanities, such as critical thinking and literary analysis, and they also learned the fundamentals of VR development. Figure 8: Students at Hamilton College combine literary analysis and VR development skills to create visual interpretations of literary works in VR. *Image source: Hamilton College.*⁷⁴



The University of the Arts launched the Center for Immersive Media in 2019, which aims to enhance the school's renowned performing arts instruction with immersive technologies such as VR, motion capture, and spatial audio.⁷⁵ Students and faculty can utilize the facility to explore the potential of AR/VR and human-computer interaction in performance and arts education.

The University of Oregon Center for Applied Second Language Studies launched the Virtual and Augmented Reality Language Training (VAuLT) program in 2018.⁷⁶ The application allows language learners to practice more realistic interactions and contextualize foreign language grammar and vocabulary in real-world settings.⁷⁷ Unlike traditional language learning approaches, VAuLT allows students to reap the benefits of real-life practice in a low-risk setting.



Soft Skills and Career Development

In addition to the value they offer in specific disciplines and subject areas, AR/VR technologies can help students develop critical soft skills that will better equip them for success in the future. This is particularly valuable for students entering fields such as law, business, and health care, where person-to-person communication, negotiation, and critical thinking skills are just as important as technical knowledge.

Career Mindset Development is an interactive VR simulation developed by digital soft skills training platform Bodyswaps as part of a partnership with further education colleges in the United Kingdom.⁷⁸ The 15-minute module allows learners who are just entering the workforce to practice workplace communication skills and provides them with feedback on both their verbal and nonverbal communication.⁷⁹

Figure 9: Participants in the Career Mindset Development module practice common workplace interactions, such as giving colleagues feedback on a presentation. *Image source: Bodyswaps.*⁸⁰



The University of Michigan Innovation Fund has awarded grants to faculty for several soft skills and leadership training projects that utilize immersive technologies.⁸¹ Projects extend across disciplines and learning objectives, including training future lawyers to give appropriate feedback in legal settings, cultivating leadership competency among nursing students, and preparing future social workers for the field.⁸²

Technical Education and Specialized Training

Like soft skills training, AR/VR can enhance technical education and specialized training by creating a low-risk, low-cost learning environment. Immersive experiences can expose learners to highly technical and even potentially hazardous activities in order to better prepare them for realworld field experience. AR/VR technologies can also expand access to technical education by reducing the need for travel to onsite training or investment in expensive equipment.

An edtech provider that builds interactive AR experiences for specialized hardware, **zSpace** offers immersive learning tools for key sectors including health sciences, advanced manufacturing, agriscience, and transportation.⁸³ In 2019, the company partnered with career and technical education resource and credentials provider NOCTI to enable students to earn up to 33 industry credentials using zSpace learning tools.⁸⁴ According to the company website, over 50 technical colleges in the U.S. have installed zSpace tools.⁸⁵



Figure 10: Edtech provider zSpace uses a combination of digital screens, glasses, and stylus controls to allow students to interact with and manipulate 3D renderings of physical objects. *Image source: zSpace.*⁸⁶ The U.S. Army's **Synthetic Training Environment** equips leaders to conduct complex trainings and simulations in synthetic environments using AR, VR, and MR.⁸⁷ This capability means trainings no longer have to be tied to a specific location or terrain, allows for more iterative and informationrich training simulations, and provides analytics that allow leaders to adjust trainings to meet specific objectives.⁸⁸

Ferris State University's **FerrisNowVR Initiative** utilizes VR technologies to deliver engaging and interactive STEM education to high school students in rural school districts across Michigan.⁸⁹ Students can dual-enroll in synchronous courses at the university and earn credits toward certificates in information technology and other technical fields – without traveling outside of their home district. Funded by a U.S Department of Agriculture Distance Learning and Telemedicine grant, the program's goal is to deploy necessary technologies to 20 high schools and career and technical education centers in 11 counties.⁹⁰

Teacher Training: Preparing Educators for Success

Children and university students are not the only audiences for education-focused immersive experiences. The same capabilities that make these technologies a valuable tool in K-12 and higher education also position them to help educators learn and grow.

TeachLivE is an immersive classroom simulator developed at the University of Central Florida's Center for Research in Education Simulation Technology.⁹¹ The program allows new or soonto-be teachers to practice responding to highstress classroom scenarios in a controlled environment. This can help teachers understand their own classroom behavior in a low-impact setting – if something goes wrong, or they react inappropriately, they can simply reset the simulation.⁹²

Teacher's Lens aims to address unconscious or implicit biases that may impact how teachers interact with female students and students of color.⁹³ Using VR, participants go through a simulated classroom interaction in which the program asks them to call on students of different races and genders. Drawing on the Harvard Implicit Association Test, the program uses this data to determine whether they exhibit unconscious



Figure 11: Teacher's Lens translates the Harvard Implicit Association Test into a VR simulation for teachers, and provides them with feedback that could help them recognize and address their own biases in classroom settings. *Image source: Debias VR via Oculus Experiences.*⁹⁵

preference and provides feedback to the participant to help educators and institutions better understand where implicit biases may exist so they can take steps to address them.⁹⁴

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ent of	Slight automatic preference for Female with Science and Male with Liberal Arts.	6%
	Moderate automatic preference for Female with Science and Male with Liberal Arts.	49%
	Strong automatic preference for Female with Science	1%

CONSIDERATIONS AND RECOMMENDATIONS FOR POLICYMAKERS

AR/VR technologies have enormous potential to transform the way students learn at all levels. But the promising future of immersive learning is not guaranteed. It is important to note that many elements beyond the technology itself will determine the success of AR/VR solutions in educational settings – and policymakers should take action to create an environment in which innovation in this sector can thrive.⁹⁶ Addressing key considerations of technical knowledge, educational content, health and safety, and accessibility can encourage more widespread adoption and incentivize ongoing innovation to realize the full potential of AR/VR as an educational tool.

Congress should direct the Department of Education to invest in programs, resources, and initiatives that will guide the development of AR/ VR educational solutions and encourage further innovation in this field.

Invest in Research on Health, Safety, and Efficacy

The potential educational benefits of immersive learning tools are evident, but there are still outstanding questions that will need to be addressed. First, there are many unknowns regarding the health and safety impacts of AR/VR technologies, particularly for younger children.97 The lack of research does not necessarily mean these technologies are unsafe. However, additional investigation of both psychological impacts (e.g., children's ability to distinguish fictional scenarios or virtual environments from the real world) and physical or physiological impacts (e.g., motion sickness, eyestrain, or potential injuries from head-worn devices) would provide more clarity for parents and educators. According to Common Sense Media, 30 percent of parents are "very concerned" about potential negative health impacts of VR on their children, which may create resistance to using these technologies in the classroom.⁹⁸ Second, as AR/VR is still a relatively nascent and rapidly evolving technology, the evidence base for the benefits of AR/VR solutions on learning outcomes is still relatively small. More research is needed to understand when and how these technologies can be most beneficial for learning, including best practices to adapt existing pedagogical approaches to immersive tools.

Providing scientific research on the safe and effective use of these devices for children will help parents, administrators, and educators make better decisions about how to use immersive technologies, especially those that utilize headworn displays, in classroom learning. The Institute of Education Sciences (IES) in the Department of Education should support research that specifically examines the health and safety impacts of immersive technologies on children. This research should include not only investigating the prevalence and severity of potential negative effects - such as psychological impacts or motion sickness - and their causes, but also best practices to mitigate these potential harms to ensure children can gain the educational benefits of immersive experiences without side effects. The Education and Health and Human Services departments should use the outcomes of this research to produce quidelines for developing and implementing immersive educational experiences for different age levels. This should include considerations of age limits and parameters for age-appropriate content, types of devices, and duration of individual experiences.99

In addition to health and safety, IES should also provide funding for research into effective uses of AR/VR technologies to enhance learning outcomes. This research should cover not only uses in K-12 classrooms but also in higher education and distance learning. A comprehensive understanding of how these technologies impact learning outcomes could help educators, administrators, and individual learners make informed decisions about when and how to add AR/VR devices and applications to existing educational tools. This research could also inform broader guidance and recommendations from the federal government, as recommended ahead.

Encourage Technical Literacy

Because AR/VR is still a relatively new technology, there is a notable technical learning curve for both students and educators that may discourage adoption. It is important that instructors have the necessary knowledge to effectively integrate AR/VR solutions in their lesson plans. Because AR/VR adoption is still in its early stages, many educators have not even been exposed to the technology in other contexts, such as training or personal entertainment.¹⁰⁰

As discussed in this report, many educators are enthusiastic about deploying these technologies in their classrooms. The Department of Education should build on this enthusiasm by offering educators training and resources for using immersive technologies. For example, the department should provide state education agencies with funding to train educators on how to use different AR/VR devices and applications and identify the best ways to integrate AR/VR technologies to meet state-level standards for classroom and distance learning. In addition, the department should provide funding for educators to enroll in courses to learn how to create basic immersive content so they can create their own materials to meet specific learning objectives.

Technical literacy also presents a challenge for adoption among learners of all ages. Because household adoption rates are still relatively low – particularly for more immersive head-worn displays – many kids' first exposure to AR/VR technologies could be in classroom settings.¹⁰¹ This is consistent with existing trends in digital literacy: According to the 2018 International Computer and Information Literacy Study, teachers are the primary source of knowledge for key information and communications technology skills such as creating digital documents and presentations and using computer programs and files.¹⁰² The Department of Education should integrate key AR/ VR skills into existing digital literacy resources and initiatives for both K-12 and adult learners, including health and safety measures, participant conduct in multiuser experiences, and the fundamentals of content development.

Accelerate Content Development

Educational AR/VR content remains in a chickenand-egg cycle. Although quantity is expanding, there is still a relative dearth of quality, relevant, age-appropriate content. This in turn keeps demand for AR/VR solutions relatively low, which discourages further efforts to develop such content.¹⁰³ And this challenge is not limited to education: In a 2021 survey of AR/VR industry leaders, 53 percent of respondents named "content offerings" as one of the top barriers to adoption of immersive technology.¹⁰⁴

Government investment in immersive educational content could break this cycle.105 There are three key channels through which this could be achieved. First, federal government bodies that already produce educational content, such as NASA and the Smithsonian Institution, should invest in developing web-based immersive content. By increasing the amount of guality and relevant immersive educational content available, these investments could encourage more educators and institutions to invest in the devices necessary to fully experience it. Further, the Department of Education should include AR/VR solutions as a priority in its investment and grantmaking activities. This could incentivize innovation both in content development and the use of these technologies in different educational contexts and subjects. Finally, the federal government should encourage colleges and universities to establish AR/VR labs and resources on their campuses. As discussed in this report, these spaces could spark interest in immersive technologies as educational tools (thereby increasing demand for content), and also encourage students and faculty to develop innovative uses of these technologies across disciplines, which would increase the range of content available.

Support Equitable Adoption

Although the cost of immersive solutions is going down, it is still prohibitive for many, particularly districts and institutions with limited resources. Schools that do have the budget for new technology solutions will likely prioritize established. proven technologies such as laptops and tablets over newer devices and applications – such as AR/ VR – that carry higher uncertainty and unfamiliarity. Fortunately, schools do not necessarily need hundreds of high-end headsets to take advantage of the benefits AR/VR educational tools offer. Many of the tools highlighted in this report are accessible on web-enabled devices including computers, tablets, and mobile phones. Funding for technologyaccess initiatives should prioritize proposals that include provisions for using these devices as immersive educational tools.

In addition, to accelerate adoption of more advanced solutions (e.g., heads-up AR and MR displays or VR headsets) in educational settings and ensure these technologies are accessible to as many learners as possible, the Department of Education should provide funding for public schools and community colleges to establish AR/VR labs that can provide immersive technology resources to students, educators, and community members. Initially, the department should provide funding for a small number of pilot centers, with preference given to rural and low-income districts where learners stand to benefit most from the opportunities these technologies present for distance and experiential learning. These preliminary initiatives could inform guidance and best practices for additional funding and encourage state and local governments to implement similar resources.

CONCLUSION

The use cases highlighted in this report represent only a sample of the ever-expanding field of immersive education. As the technology continues to advance and gain more widespread adoption, new possibilities will undoubtedly emerge.

Going forward, it will be important to ensure instructors have the necessary skills and knowledge to implement AR/VR solutions in their lesson plans and create opportunities to develop necessary content, including equipping students and educators with the skills to do so. Policymakers should support further innovation by facilitating content development, investing in necessary research into safety and efficacy, and supporting efforts to expand access to these technologies.

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